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Response to Christopher M. Long and Peter Valberg (2007) "Comments on *Brown et al. (2007) An Assessment of Risk from Particulate Released from Outdoor Wood Boilers.*" *Hum. Ecol. Risk Assess.* 13(1)

We respond to comments from Drs. Long and Valberg, consultants for a manufacturer of outdoor wood boilers (OWB). Similar comments, prepared on behalf of their industrial client, were circulated by their client, well before our article was published. It wasn't until three weeks later that we received those comments from their client's attorney demanding that we rescind our publication. We stand by our article. The following response to the Gradient comments ignores the comment writers' hyperbole.

FIVE METHODOLOGICAL FLAWS ARE ALLEGED IN THE GRADIENT COMMENTS

1. Long and Valberg allege that our "reliance on a total of 4.3 hours of ambient air measurement data as an estimate of lifetime (*e.g.*, 30-year) exposure in the cancer risk assessment" is flawed.

The data set is incorrectly characterized by Long and Valberg. It consists of selectively sampled stages of the burning process over a two-day period under the basic four operating conditions encountered in central New York during wintertime. Moreover, Johnson's findings (Johnson 2006) are completely consistent with the modeled material cited in NESCAUM (2006), highlighted in footnotes 8 and 9 of our article, and presented in the Discussion section on page 204. Johnson's work (2006) is the first and only available field monitoring data of any OWB. Long and Valberg minimize the extent and quality of the supporting information described in both this and in the Johnson (2006) article.

We also agree with Johnson (2006) that more extensive monitoring is necessary. These devices have been sold for two decades. We were aware of no other published near-field monitoring (downwind) exposure data. Meanwhile, potentially serious human exposures may be occurring. A quantitative risk assessment using the available data was necessary to evaluate the public health hazard under such circumstances.

2. Long and Valberg refer to "a well known tendency of light scattering monitors such as the DataRAM to overestimate ambient $PM_{2.5}$ concentrations, particularly in wood smoke."

As noted in Johnson (2006), the U.S. Forest Service (USFS) uses the DataRAM to provide general trends of ambient wildfire smoke $PM_{2.5}$ concentrations. The USFS report (USDA 2001) should not be used to adjust the DataRAM DR4, the instrument used by Johnson (2006), response to ambient wood smoke particulate matter. The USFS DataRAM correction factor of 0.37 to 0.48 is used to align findings with gravimetric (filter-based) Federal Reference Method data that serve as a control in the USFS study. The DataRAM is sensitive to high humidity conditions such as those present in a forest fire (*i.e.*, new wood burning and other materials consumed in a forest fire produce a great deal of water vapor). Johnson (and others) noted that the DataRAM DR4 autocorrects for airborne particles likely to grow by accretion of water from situations of high humidity (greater than 65% to 70%). The relative humidity ranged from 28–55% on the day Johnson performed measurements in central New York in March. Our experience and that of the Forest Service is that the instrument is accurate under such conditions for ambient monitoring when compared to non-gravimetric real-time ambient monitors. Moreover, if the "correction" were applied it would not appreciably change the estimated cancer risk. The correction is not necessary and would underestimate the actual ambient $PM_{2.5}$ levels.

3. Long and Valberg state that "one of the more serious errors in the article involves derivation of the 'conversion factor' of 6.9 that Brown *et al.* use to adjust for. . . 'scaling differences in burn box capacity' (*i.e.*, wood stove *vs.* OWB)."

Long and Valberg have made an error in basic arithmetic. The New York State Attorney General's report (NYEPB 2005) does not report, as Gradient's consultants incorrectly interpret, the amount of PAH bound to the particulate, nor can that information be obtained from the New York report. Table 2 of the New York report presents the average hourly release of particulate matter and the average hourly release of PAH from various wood combustion units. Long and Valberg, to support their assertion, assumed that one can divide the average PAH by the average particulate matter from the New York data and derive the average PAH per particulate. That is not an estimate of the average PAH per unit particulate. The only way to obtain the average of a series of ratios is by averaging the individual ratios. Their quotient of 0.58 is neither arithmetically nor scientifically valid.

A comparison of PAH from outdoor and indoor fire boxes is appropriate when one considers that not *all* PAH are adsorbed. This is why they are called semi-*volatiles*. It appears that Long and Valberg assume that 100% of the PAH is particulate bound. There is no evidence that 100% of the PAH is adsorbed onto the particulate matter.

Moreover, although we did not sum risk from other vapors released (formaldehyde, benzene, *etc.*), there is a need to consider that PAH released in another form would increase, not decrease the cancer risk estimate.

THE COMPLETE PICTURE

4. Risk assessment must consider the health context. Long and Valberg evidently do not understand the importance of capturing both indoor and episodic exposures and the role that these exposures play in the full characterization of health risks posed by OWB devices. Their comment: "despite taking a bold step of proposing their own metric for quantifying acute health risk of PM (the "Unhealthy Air Day Concept"), Brown *et al.* demonstrate a limited understanding of the state of science regarding PM health effects literature."

Based on Henderson *et al.* (2007), this concept may not be as *bold* as Long and Valberg suggest. There are several instances where Long and Valberg claim that we incorrectly cite longer term studies as evidence of short-term health effects. Taken in the context of the Risk Characterization in the article, references such as Dockery *et al.* (1993), Dockery (2001), and Koenig *et al.* (1993) form the basis for interpretation of short-term effects studies. These references provide evidence of occurrences of health effects at the ranges of particulate matter measured in ambient air.

Comments such as "Brown *et al.* misrepresent the Dockery *et al.* (1993) study" reveal a misunderstanding of the argument and risk characterization process. Dockery and others specified endpoints of concern from particulate matter exposures, but more importantly excluded other endpoints. Their work thus provides the specificity necessary to assess the target actions of the short-term risks. The risk characterization in our article examined evidence of short-term risks from particulate matter from wood smoke. The particulate studies of Gent *et al.* (2003) and Peters *et al.* (2001) provide the short-term exposure data necessary to establish the inhaled doses at which the observed health effects occur. This work established a range of exposures necessary to estimate the risk based on inhaled dose. The logic is sound. Subsequent comments by Long and Valberg are not relevant to the assessment of the acute risk to susceptible populations.

5. Long and Valberg's assertion that the Air Quality Index (AQI) adequately considered cardiovascular effects and that no other metric is necessary is disingenuous.

The AQI was introduced prior to 1997 and the first observation of short-term cardiovascular effects by Peters *et al.* (2001) was four years later. That notwithstanding, our statement that the AQI "does not consider specific cardiopulmonary risks" should be read in context, that is, currently no standards exist for acute or carcinogenic risks from local exposures to OWB wood smoke or other particulate. AQI refers to ambient particulate matter levels from any number of sources. The current National Ambient Air Quality Standards (NAAQS) do consider cardiovascular actions of particulate matter in ambient air, but the NAAQS do not consider episodic exposures, such as might be experienced living downwind from an OWB.

Irrespective of this, our proposed Unhealthy Air Day approach is designed to capture the relationship between micro-meteorological conditions that arise when outdoor smoke infiltrates the indoor environment and human exposures that result from delayed clearance from the house. The Unhealthy Air Day risk is based on the inhaled dose over a period of 6 hours. High episodic risk involves inhaled doses of 250 μg or more. That inhaled dose calculation is not based on the NAAQS standard,

but rather on observed responses at those concentrations in the literature cited. Our article makes the argument that a 24-hour ambient air standard is not protective of the acute responses. The inhaled dose allows the public health regulator to consider "personalized" dosing to assess the many variables to estimate actual personal exposure.

Others have also pointed out that the 24-hour NAAQS may not be health protective (Delfino *et al.* 2002; Johnson and Graham 2005). The 24-hour NAAQS is applied to general ambient air, and cannot be used as a measure of compliance for localized risks such as those induced by the OWB emissions because they fail to estimate exposure during periods of poor air mixing. Our modeled data indicate that the amount of particulate matter present from the OWB places the 6-hour exposure in the range of exposures shown in the cited human studies to exacerbate cardiovascular and lung disease. Based on their comments, it appears that Long and Valberg fail to understand the actual acute public health risks being addressed.

Currently there are public exposures to wood boiler emissions with serious potential for health risks. Johnson (2006) revealed that there are extremely troubling levels of exposures from a single relatively small OWB device, apparently operated according to directions of the manufacturer. Our publication places a quantitative perspective on the human hazard using the best available information and scientific analysis.

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